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Nutritional, sensory and physicochemical properties of peanut beverage sterilized under two different UHT conditions

I. Y. S. Rustom,[a]* M. H. López-Leiva[a] & B. M. Nair[b]

[a]*Department of Food Engineering, Chemical Centre, University of Lund, P.O. Box 124, S-221 00 Lund, Sweden*
[b]*Department of Applied Nutrition, Chemical Centre, University of Lund, P.O. Box 124, S-221 00 Lund, Sweden*

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Chocolate-flavoured peanut beverage was UHT-sterilized at 137°C for 4 s (C04) or 20 s (C20) and aseptically filled in Tetra brik cartons. Microbiological, physicochemical, sensory and nutritional properties of the beverages were evaluated. No bacterial cells, spores, yeasts or moulds were observed. The power law described the rheological behaviour ($k = 0.28$, $n = 0.53$). Stability of C04 and C20 was high as indicated by the low homogenization (0%) and sedimentation (0.15 and 0.20 ml/12 ml) indices. C20 was darker and less viscous than C04. The sensory and nutritional properties of C20 did not significantly differ from those of C04. Aroma and taste mean scores were (4.2/5) and (3.8/5), respectively, and correlated with acceptability (5.4/7). Bitterness was not perceived in any sample. C04 contained (g/ 100 g beverage) protein (3.0), fat (5.2) and carbohydrates (9.6). It also contained (mg/100 g beverage) thiamin (0.3), vitamin E (0.7), niacin (1.4), iron (0.5), copper (0.2), manganese (0.2), vitamin A (3.6 μg RE), riboflavin (0.01), vitamin C (0.4) and calcium (5.5). The contents of essential amino acids were (mg/g protein) cystine + methionine (17), histidine (17), isoleucine (30), leucine (67), lysine (26), threonine (20), tryptophan (13), tyrosine + phenylalanine (69) and valine (35). The *in vitro* protein digestibility was 75%, and the protein digestibility corrected amino acid score (PDCAAS) was 34%.

INTRODUCTION

Short supply of milk in various countries and the need for alternatives have motivated the development of beverages from locally available raw materials of plant origin such as soybeans (Ang *et al.*, 1985), peanut (Elahi & Ali, 1971; Schmidt & Bates, 1976; Rubico *et al.*, 1989), cowpeas (Akinyele, 1991) and cereal grains (Singh & Bains, 1988).

We have developed an extract from peanut solids based on maximum recovery of the solids with water, and suitable composition of the extract (Rustom *et al.*, 1991*a*,*b*, 1993*a*). Ultra high temperature (UHT) treatment (130°C, 20 s) at pH 5.0 and pH 10.2 significantly reduced the mutagenic activity of aflatoxin B_1 in artificially contaminated peanut extract (Rustom *et al.*, 1993*b*). In the present work, a peanut extract was processed into a beverage, after addition of sugar, emulsifier, cacao powder and flavour. The beverage was homogenized, UHT-sterilized and aseptically filled in Tetra brik cartons. The objective was to study the physicochemical characteristics as well as the microbiological, sensory and nutritional features of the beverage after UHT sterilization at (137°C, 4 s) or (137°C, 20 s).

*To whom correspondence should be addressed.

MATERIALS AND METHODS

Papain (P 3375) was from Sigma Chemical Co. (St. Louis, MO, USA). Recodan CM® was from Grindsted (Brabrand, Denmark). Peanuts, imported from Thailand, were purchased from the local market (Bangkok Trading, Malmö, Sweden). The testa-free peanut kernels were composed of 6.2% (w/w) moisture, 25.3% protein, 51.5% fat, 2.8% ash and 14.2% carbohydrates. Vanilla aroma was from Ekströms Konsumentkontakt (Örebro, Sweden). Rom-Cacao flavour was from AB Einar Willumsen (Malmö, Sweden). Sugar and cacao powder were purchased from the local market in Lund, Sweden.

Extraction of peanut solids

Two batches, 120 litres each, of peanut extract were prepared. Peanut kernels were heated for 20 min at 80°C in an electric oven with air circulation (IFÖ Kampri, type T 2008, Kampri Storkök, Sweden) followed by mechanical abrasion of the kernels between two rough metal plates (done by hand). Peanut red skins (testa) were thereafter manually separated from the kernels. The clean testa-free kernels were ground twice to a paste in a meat mincer (Electrolux, type 1987/R20, Electrolux, Denmark). Two extraction steps were conducted in a stainless steel tank equipped with two propellers. In the first step, 90 litres of tap water were heated in the extraction tank to 50°C followed by adjustment of the pH to 8.0 with 1 N NaOH. Papain powder (52.5 g) was thereafter dissolved in the mixture. The peanut paste (15 kg) was added and the mixture was continuously stirred for 30 min at 50°C. In the second step, peanut solids remained from the first step were extracted with 30 litres water for 30 min at 50°C and pH 8.0. The extract was filtered through a nylon filter with uniform pores (160×120 μm) followed by clarification in a disc bowl separator (Alfa-Laval, type 29AE/1963, Lund, Sweden) operated at 4000 rpm.

Beverage processing

Two chocolate-flavoured peanut beverages, 100 litres each, were prepared. Each beverage was made of 90.27% (w/w) extract, 8.35% (w/w) sugar, 0.40% (w/w) Recodan CM® (monodiglycerides + glycerol monostearates + guar gum + carrageenan) emulsifier, 0.39% (w/w) Rom-Cacao flavour, 0.10% (w/w) vanilla and 0.49% (w/w) cacao powder. The beverage was processed according to the following steps: the extract was heated to 65°C in a steam-jacketed tank, agitated with an impeller (Bredo mixture, Paul Muller Co., Germany). The other ingredients were then added and mixed for 20 min at 65°C. The mixture was thereafter homogenized at 72°C and 250 bar (200 + 50) followed by UHT sterilization (Sterilab®, indirect module, Alfa-Laval, Lund, Sweden) at 137°C for 4 s (beverage C04) or at 137°C for 20 s (beverage C20). The beverages were aseptically packed (Tetra Pak, type AB3-250, Tetra Pak, Lund, Sweden) in 250 ml Tetra Brik® cartons (ABS Doplex, 175 g/m^2) made of composite layers of: low density polyethylene–paper board–aluminium foil–low density polyethylene.

Physicochemical properties

Rheological properties
Fundamental rheological measurements were carried out at 20°C using coaxial rotational searle-type viscometry (Bohlin Visco 88 BV, Bohlin Reologi AB, Lund, Sweden).

pH
The pH was measured at 20 ± 2°C with an electronic pH meter (PHM62, Radiometer, Copenhagen, Denmark).

Homogenization and sedimentation indices
The homogenization and sedimentation indices were determined as mentioned earlier (Rustom *et al.*, 1995).

Colour
A tristimulus colorimeter (Dr Lange Micro Colour, Dr Bruno Lange GmbH, Berlin, Germany) was used to measure the colour, as mentioned previously (Rustom *et al.*, 1995).

Microbiological assay

Sterility control test was performed according to procedures described by Alfa-Laval company (Alfa-Laval, 1983). Immediately after the sterilized product was aseptically filled, 20 cartons were stored at 37°C for 9 days. Contents of the cartons were thereafter analysed for presence of bacterial vegetative cells and spores. The cartons were thoroughly shaken, sprayed with 70% ethanol and opened with a sterile scalpel. A sample (10 μl) was taken with a sterile loop from each Brik and smeared on tryptone glucose extract agar (Oxoid, Hampshire, UK) plates to determine the total counts of vegetative cells. The beverages stored at 37°C for 9 days were analysed for presence of spores after being heated (80°C, 10 min), smeared on tryptone glucose extract agar and incubated at 37°C for 4 days. The standard International Dairy Federation procedures were followed to determine counts for yeasts and moulds (IDF, 1990).

Sensory evaluation

Sensory evaluation was performed using descriptive analysis and affective testing (Stone & Sidel, 1985). Thirteen panellists participated. The panellists consisted of staff members and graduate students in the departments of Food Engineering, Food Chemistry and Applied Nutrition, Chemical Centre, Lund University, Lund. Post-panel discussions were not conducted. A five-point unstructured descriptive scale was used to rate attributes of colour strength (1 = light, 5 = dark), aroma (1 = bad, 5 = good), taste (1 = bad, 5 = good), bitterness (1 = no bitter after-taste, 5 = strong bitter after-taste). Perception of off-flavours was judged qualitatively as 'present' or 'absent'. The panellists were asked to identify the off-flavours as rancid, fermented, beany, peanut, unidentified or others. A seven-point structured hedonic scale (1 = dislike extremely, 4 = neither like or dislike, 7 = like extremely) was used to score acceptability of the beverages. The panel was conducted under yellow light in a special room provided with partitioned conventional sensory booths. The beverages (50 ml) were served refrigerated (10°C) in 100 ml colourless transparent plastic cups coded with four-digit random numbers. Fresh water was provided to rinse between successive evaluations.

Nutritional quality

The samples (C04 and C20) were freeze-dried and stored at 5°C for determination of the nutritional quality. Three replicates of each beverage were analysed.

Chemical composition

The beverage was analysed for nitrogen content using a Kjeltec Auto 1030 Analyzer (Tecator AB, Höganäs, Sweden). A factor of 5.46 was used to calculate the protein content (Woodroof, 1969). Contents of total solids and ash were evaluated according to the methods of the Association of Official Analytical Chemists (AOAC, 1984). Fat content was determined using the Gerber method (SMR, 1970). Glucose, fructose and sucrose were determined using a kit from Boehringer Mannheim (cat. No. 716 260, Boehringer Mannheim Gmbh, Germany). Glucose and fructose were measured spectrophotometrically (340 nm) as reduced nicotinamide–adenine dinucleotide phosphate (NADPH) after reaction with adenosine triphosphate and nicotinamide–adenine dinucleotide phosphate (NADP). Sucrose was inverted to glucose and fructose using fructosidase. The sucrose content was calculated from the difference of the glucose concentrations before and after inversion. Lactose was determined as glucose after hydrolysis with galactosidase to glucose and galactose using a kit from Boehringer Mannheim (cat. No. 986 119, Boehringer Mannheim Gmbh, Germany). The concentration of glucose was, thereafter, measured spectrophotometrically at 340 nm. Starch was determined as glucose after incubation with Termamyl® and amyloglucosidase, using a method described by Holm *et al.* (1986). The starch content was calculated as glucose concentration × 0.9. Soluble and insoluble dietary fibre were determined using a gravimetric enzymatic method described by Asp *et al.* (1983).

Amino acid analysis

Ion-exchange chromatography (Biotronic LC 5001 amino acid analyser) was used to determine amino acid composition of the freeze-dried samples after hydrolysis with HCl (Nair, 1977). Cysteine and methionine were determined as cysteic acid and methionine sulphone, respectively, after performic acid oxidation followed by acid hydrolysis (6 N HCl). Tyrptophan was assayed spectrofluorimetrically after incubation with papain in urea. The chemical scores for amino acids were calculated based on recommendations of the FAO/WHO/UNU (1985) expert consultation group for different age groups.

***In vitro* protein digestibility**

The *in vitro* protein digestibility was determined using a method described by Satterlee *et al.* (1982). Two solutions were used to measure the *in vitro* protein digestibility on the freeze-dried beverages containing 10 mg nitrogen. Solution A contained 227040 BAEE units of trypsin, 1860 BTEE units of α-chymotrypsin and 0.520 L-leucine β-naphthylamine units of peptidase dissolved in 10 ml distilled water. Solution B contained 65 casein units of bacterial protease in 10 ml distilled water. Both solutions were adjusted to pH 8.0 ± 0.03 at 37°C and then held at 0°C on ice. The reference protein was 10 g Na-caseinate (ANRC) suspended in 200 ml water with pH adjusted to 8.0 ± 0.03 with NaOH and held for 1 h at 4°C before use. The samples plus water (10 ml) were held at 20°C for 2 h, then placed at 37°C and the pHs were adjusted to 8.0 ± 0.03 with NaOH with continuous stirring. One ml of solution A was added to the samples while stirring. Exactly 10 min after adding solution A, 1 ml of solution B was added, and the beaker was transferred to a water bath at 55°C; after 9 min the beaker was transferred back to the 37°C water bath and the pH measured within 1 min. The pH of the control casein should be 6.42 ± 0.05, and the protein digestibility was calculated as: Digestibility = $234.84 - 22.56\ (X)$; where (X) is the pH for the sample at the end of digestion.

Mineral analysis

The freeze-dried beverages (1.0 g) were treated with 20 ml of concentrated HNO_3 for an overnight period followed by digestion at 115–120°C, for about 3 h, until the acid evaporated. The digested samples were diluted 12 times with milli-Q water, and filtered through a disposable Sterile 1.2 μm micro filter. The concentrations of Ca, Mg, Fe, Zn, Cu and Mn were determined using flame atomic absorption spectrophotometry (Varian Techtron AA 1275, Springvale, Australia). with air–acetylene flame. The samples were further diluted with a 3.12% solution of lanthanum chloride in 10% HNO_3 (1:10) for Ca and Mg analysis, with 2.5 M HCl for Fe (1:2) and Zn (1:20) analysis, and with milli-Q water for analysis of Cu (1:5) and Mn (1:10). Atomic emission spectrophotometry (Varian Techtron AA 1275, Springvale, Australia) was used for analysis of Na and K after diluting (1:100) the samples with a 0.13% solution of CsCl in 10% HNO_3. Citrus leaves (Analytical Standards AB, Kungsbacka, Sweden) were used as a standard reference to assess the accuracy and precision of the analysis. The mean content ($n = 2$) of Ca, Mg, K, Cu, Fe, Mn, Na and Zn deviated by 0.4, −7.9, 4.9, 8.5, −6.7, −1.3, 5.0 and 5.9%, respectively, from the certified values for the citrus leaves.

Vitamin A (retinol) and vitamin E (α-tocopherol)

Vitamin A (retinol) and vitamin E (α-tocopherol) were determined as described by Ruales & Nair (1993). The sample was hydrolysed with alkaline ethanol (potassium hydroxide–ethanol–water), followed by extraction of the vitamins with *n*-hexane. Separation and detection of the vitamins was performed using HPLC.

Vitamin B1 (thiamin)

Thiamin was assayed spectrofluorimetrically, as described by Ruales & Nair (1993), as thiochrome. Thiamin was released from the sample by acid hydrolysis (0.1 M HCl) followed by enzymatic hydrolysis (Clara-diastase). Thiamin was separated by filtration, oxidised to thiochrome with NaOH and $K_3Fe(CN)_6$, and detected using HPLC.

Vitamin B2 (riboflavin)

Riboflavin was assayed spectrofluorimetrically, as described by Ruales & Nair (1993), after acid hydrolysis (0.1 M HCl) and enzymatic (acid phosphatase) digestion. Riboflavin was separated and assayed using HPLC.

Vitamin C (ascorbic acid)

Vitamin C was determined according to Lookhart *et al.* (1982). The sample was extracted with 0.7 mM dithiothreitol, and clarified using centrifugation (4550*g*, 10 min) and filtration (0.45 μm). Content of vitamin C was measured using HPLC.

Folic acid

Folic acid was determined microbiologically as described by Ruales & Nair (1993).

Niacin

Niacin was determined microbiologically as described by the Association of Official Analytical Chemists (AOAC, 1984).

Nutrient density

The nutrient density of the beverage was calculated for protein, vitamins and minerals as described by Hansen (1973). Reference calorie intake was taken as 2800 kcal/day which corresponds to the average of recommended dietary allowances for adult males in the age groups 19–22 (2900 kcal/day) and 23–50 (2700 kcal/day) years (Kreutler, 1980).

Statistical analysis

Statistical analysis was performed using Stat View® software (Stat View, 1988). One-way analysis of variance (ANOVA) was done to elucidate the effect of the UHT treatment conditions on physicochemical and nutritional properties of the beverage. Multiple comparison tests were performed adopting Fisher's Protected Least Significant Difference test (Fisher PLSD) at 95% confidence level. Non-parametric statistics (Mann–Whitney unpaired, two-tailed test at $\alpha = 0.05$) was used to compare sensory properties of the beverage as affected by the UHT treatment conditions (Siegel & Castellan, 1988). Measures of association among the sensory attributes were evaluated using the Spearman Rank-order Correlation Coefficient test (two-tail), after correction for ties, at $\alpha = 0.05$ (Siegel & Castellan, 1988).

RESULTS AND DISCUSSION

Physicochemical properties

The beverages sterilized (137°C) for 4 or 20 s had similar rheological properties. The viscosity curve of beverage C04 is shown in Fig. 1a. The beverage was pseudoplastic; the viscosity decreased with increase in shear rate.

Many non-Newtonian fluids follow the power law: $\log \tau = \log k + n \log \gamma$; where τ is the shear stress, γ is the shear rate, k is the consistency index and n is the flow behaviour index. The power law is usually applicable in a limited shear rate range. It is an empirical model with no physical meaning of the constants k and n, but they are useful in designing flow processes. Log (shear stress) was plotted vs log (shear rate) in Fig. 1b. The power law described the flow behaviour of the beverage in the shear rate range of 81–1284 l s^{-1} with k and n values of 0.28 and 0.53, respectively.

Physicochemical properties of the beverages are summarized in Table 1. Sterilization (137°C) for 4 or 20 s gave beverages with similar pH. The pH was 8.0 before sterilization, and dropped to 7.7 after UHT treatment probably as a result of protein unfolding, through denaturation by heat, and release of protons and, consequently, lower pH. Similarly, Venkatachalam *et al.* (1993) reported a decrease in the pH of skim milk immediately after UHT sterilization.

Viscosity of the beverages measured semi-empirically using a Höppler viscometer is given in Table 1. The beverage sterilized (137°C) for 20 s had significantly ($P = 0.05$) lower viscosity than the one sterilized for 4 s. Thus, the more severe sterilization conditions seemed to lower the rate of protein–solvent interactions in the

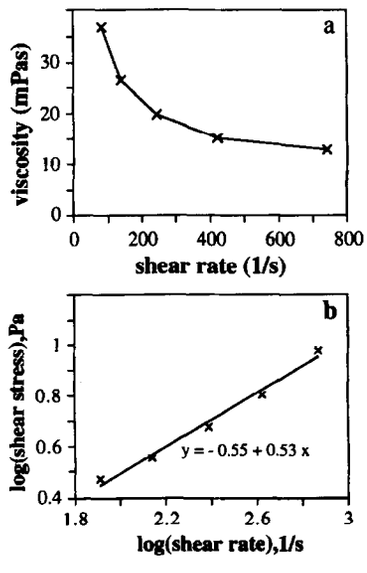

Fig. 1. Rheograms of peanut beverage UHT-sterilized at 137°C for 4 s.

Table 1. Physicochemical properties of UHT-sterilized peanut beverage

Property	UHT conditions[1]	
	137°C, 4 s	137°C, 20 s
pH	7.7[d]	7.7[d]
Viscosity (mPas)[2]	12.5	7.5
Homogenization index (%)	0.0[e]	0.0[e]
Sedimentation index (%)	0.15	0.20
Colour[3]		
hue	34.9	15.6
chroma	15.4	24.9
lightness	24.2	19.5

[1]Means in the same row followed by the same letter are not significantly different by Fisher PLSD test at 95% confidence level.
[2]Measured (at 20°C) using Höppler viscometer.
[3]Hue = $\tan^{-1}$ (b^*/a^*), chroma = $\sqrt{a^{*2} + b^{*2}}$, a^* and b^* are the CIE-LAB colour units.

beverage leading to reduced swelling of the proteins and, hence, lower viscosity.

Homogenization index (HI) was a measure of emulsion stability of the beverages. Values of HI from 0 to 10% indicated excellent stability, between 11 and 20% good stability, and greater than 20% poor stability (SMR, 1970). The beverages had excellent emulsion stability as indicated by 0% HI. Also, no visual fat separation was observed in the beverages. Sterilization (137°C) for 4 or 20 s gave beverages with similar HI.

Sedimentation index, SI (i.e. accelerated sediment formation), was a measure of stability of particles in the beverages. The dry sediment weight after centrifugation was 92% protein. Therefore, formation of the sediment was attributable to coagulation of the protein owing to its denaturation during UHT treatment. More sediment formed in the beverage sterilized (137°C) for 20 s (0.20 ml/12 ml) than in the one sterilized for 4 s (0.15 ml/12 ml). This could be caused by a reduction in protein solubility owing to increased denaturation at the more severe heat treatment. Similarly, Wilson *et al.* (1960) found that the amount of sediment increased with severity of heat treatment of whole milk. Presence of aggregated large particles and sediment is a texture defect in liquid foods leading to chalky mouth feel. However, no sediment was observed in the beverages before centrifugation.

The beverage sterilized (137°C) for 20 s was significantly ($P = 0.05$) darker than the one sterilized for 4 s suggesting an increased rate of development of Maillard reaction browning products. Also, the hue and chroma values for the two beverages were significantly ($P = 0.05$) different.

Microbiological quality

No vegetative bacteria, spores, yeasts or moulds were detected in the beverages. Therefore, the beverage can be kept at elevated temperatures for a long time.

Table 2. Sensory properties of UHT-sterilized peanut beverage

Sensory attribute[1]	UHT conditions[2]	
	137°C, 4 s	137°C, 20 s
Colour strength	3.1 ± 0.2^a	3.3 ± 0.2^a
Aroma	4.3 ± 0.2^b	3.8 ± 0.3^b
Taste	3.8 ± 0.2^c	3.5 ± 0.3^c
Bitterness	1.2 ± 0.1^d	1.2 ± 0.1^d
Acceptability	5.4 ± 0.3^e	5.2 ± 0.3^e

[1]Colour strength (1 = light, 5 = dark); aroma (1 = bad, 5 = good); taste (1 = bad, 5 = good); bitterness (1 = no bitter after-taste, 5 = strong bitter after-taste); acceptability (1 = dislike extremely, 4 = neither like or dislike, 7 = like extremely).
[2]Means ± SE ($n = 26$). Means in the same row followed by the same letter are not significantly different by Mann-Whitney unpaired, two-tailed test corrected for ties ($\alpha = 0.05$).

Sensory properties

Sensory properties of the beverages are summarized in Table 2. Spearman correlation coefficients between acceptability and sensory attributes of the beverages are listed in Table 3. Mean scores for colour strength, aroma, taste, bitterness and acceptability for the beverage sterilized (137°C) for 4 s were not significantly different from those for the beverage sterilized for 20 s, as revealed by Mann–Whitney unpaired test ($P = 0.05$). However, the beverage sterilized (137°C) for 4 s had a slightly higher mean score (5.4/7) for acceptability than the beverage sterilized for 20 s (5.2/7).

The mean score for colour strength of the beverage sterilized (137°C) for 4 s was about the mid-point (3.1/5) of the descriptive scale, indicating that the beverage had medium colour strength as appreciated by the panellists. Instrumental measurements of colour lightness showed significant differences in colour lightness between the beverage sterilized (137°C) for 4 s and the one sterilized for 20 s (Table 1), and thus indicating that the panellists could not perceive the differences in the colour strength. The colour strength did not contribute to the acceptability of the beverages as revealed by a non-significant ($P = 0.188$) correlation between the colour strength and acceptability scores (Table 3).

Aroma of the beverage sterilized (137°C) for 4 s was appreciable (mean score = 4.3/5). High appreciation of the aroma significantly ($P = 0.015$) contributed to high scores for acceptability of the beverages (Table 3).

Table 3. Spearman correlation coefficients (r_s) among acceptability and sensory attributes of UHT-sterilized peanut beverage[1]

Sensory attribute	r_s	P
Colour strength	−0.263	0.188
Aroma	0.488	0.015
Taste	0.587	0.003
Bitterness	−0.245	0.221

[1]r_s and probability (P) are corrected for ties.

Table 4. Chemical composition of the beverage (100 g)[1]

Constituent	Composition
Total solids (g)	18.0
Protein[2] (g)	3.0
Fat (g)	5.2
Ash (g)	0.2
Total carbohydrates (g)	9.6
glucose (mg)	3.6
fructose (mg)	3.6
lactose (mg)	0.0
sucrose (g)	9.2
starch (mg)	0.0
dietary fibre (mg)	347.0
soluble (mg)	169.0
insoluble (mg)	178.0
Energy (kcal)	103.0

[1]Sterilized at 137°C for 4 s.
[2]Nx5.46 (Woodroof, 1969).

Taste of the beverage sterilized (137°C) for 4 s was good (mean score = 3.8/5), and it significantly ($P = 0.003$) contributed to acceptability of the beverage as revealed by a positive correlation between the taste and acceptability scores (Table 3).

The panellists did not perceive off-flavours or bitter after-taste in any of the beverages. Bitter components are saponins which exist in the germs of peanut kernels (Dieckert & Morris, 1958). During skin removal and cleaning of the kernels, most of germs were removed, which probably contributed to absence of bitter after-taste in the beverages.

Nutritional quality

The chemical composition of the beverage is given in Table 4. The beverages sterilized (137°C) for 4 or 20 s had a similar composition. The beverage contents of total solids, protein, fat and carbohydrates complied with the recommendations of the Protein Advisory Group, PAG (1973) for milk-substitutes of vegetable origin. The PAG recommends at least 11% total solids, 2% fat, 9% non-fat solids and 3.4% protein (N×6.25). Total carbohydrates of the beverage were glucose (3.6 mg/100 g), fructose (3.6 mg/100 g), sucrose (9.2 g/100 g) and dietary fibre (347.0 mg/100 g). The beverage does not contain any lactose, which makes it of special interest to lactose-intolerant people. The beverage contained small amounts of soluble (169.0 mg/100 g) and insoluble (178.0 mg/100 g) dietary fibre. Thus most of the carbohydrates in the beverage are a source of easily available energy. Content of energy in the peanut beverage (103 kcal/100 g) was higher than that of chocolate-flavoured milk (96 kcal/100 g) and of a commercially available soybean drink (54 kcal/100 g), mainly owing to the high fat content in the peanut beverage (5.2%) as compared to the chocolate-flavoured milk (2.5%) and the soybean drink (2.0%).

Amino acid profile of protein in the beverage is given in Table 5. Only slight quantitative changes occurred in

Table 5. Amino acid composition (mg/g protein) of the beverage

Amino acid	UHT (137°C)		Milk	FAO/WHO/UNU requirement[1]			
	20 s	4 s		Infant	Children (years)		Adults
					(2–5)	(6–12)	
Alanine	33	30					
Arginine	107	93					
Aspartic acid	109	97					
Cystine + methionine[2]	17	17	33	42	25	22	17
Glutamic acid	205	180					
Glycine	50	43					
Histidine[2]	19	17	27	26	19	19	16
Isoleucine[2]	28	30	47	46	28	28	13
Leucine[2]	65	67	95	93	66	44	19
Lysine[2]	31	26	78	66	58	44	16
Proline	32	26					
Serine	47	41					
Threonine[2]	23	20	44	43	34	28	9
Tryptophan[2]	10	13	14	17	11	9	5
Tyrosine + phenylalanine[2]	75	69	102	72	63	22	19
Valine[2]	37	35	64	55	35	25	13
Limiting amino acid[3]			try	lys	lys	lys	cys + met
Chemical score[3]			127	39	45	59	100
Protein digestibility (%)[4]	75.4[c]	74.7[c]	89				
PDCAAS (%)[5]	34		113				

[1]FAO/WHO/UNU (1985).
[2]Essential amino acid.
[3]For the beverage sterilized at 137°C for 4 s.
[4]Values in the same row with the same letter are not significantly different (Fisher PLSD, $\alpha = 0.05$).
[5]Protein digestibility corrected amino acid score.

Table 6. Vitamin and mineral contents in the beverage (mg/100 g)

Component	UHT (137°C)[1]		PAG[2]
	4 s	20 s	
Vitamin A (μg RE/100 g)	3.6[a]	3.6[a]	50.0
Thiamin	0.3[b]	0.3[b]	0.15
Riboflavin	0.01[c]	0.01[c]	0.15
Vitamin C	0.4[d]	0.4[d]	3.0
Vitamin E (α-TE)	0.7[e]	0.6[e]	
Folic acid (μg/100 g)	13.0[f]	13.0[f]	5.0
Niacin	1.4[g]	1.2[g]	1.0
K	84.5		
Na	24.2		
Mg	9.2		
Ca	5.5		100.0
Fe	0.5		0.4
Zn	0.3		
Cu	0.2		
Mn	0.2		

[1]Means in the same row with the same letter are not significantly different (*t*-test, $\alpha = 0.05$).
[2]Recommendations of the Protein Advisory Group (PAG, 1973).

the amino acid profile of the beverages sterilized (137°C) for 4 or 20 s. Similarly, Rubico *et al.* (1989) observed slight differences in amino acid profile of the proteins in a peanut beverage heated at 122°C for 3 s or for 15 min. Amino acid profile of the beverage revealed that the beverage had lower protein quality than milk (Table 5), but comparable to that of a UHT-sterilized soybean drink (Ang *et al.*, 1985).

Essential amino acids requirement pattern for different age groups as recommended by the joint FAO/WHO/UNU (1985) expert consultation group is given in Table 5. Chemical scores of essential amino acids in the beverage sterilized at 137°C for 4 s were calculated and presented in Table 5. The beverage contained lower amounts of cystine + methionine, histidine, lysine and threonine than recommended for children between 2 and 12 years of age. Also, contents of all essential amino acids were below the levels recommended for infants. Lysine was the limiting amino acid for infants and children between 2 and 12 years old. Peanut proteins in peanut seeds (Neucere *et al.*, 1972; Ghuman *et al.*, 1990; Basha, 1991), defatted flour (Alid *et al.*, 1981; Wattanapat *et al.*, 1994) and protein curd (Mohamed *et al.*, 1989) were also found to contain lower amounts of lysine, cystine, methionine, threonine, isoleucine and histidine with lysine, cystine and methionine as the limiting amino acids.

In vitro protein digestibility of the beverage was not significantly ($P = 0.05$) affected by the sterilization time. The digestibility of the beverage (75%), as measured by a drop in pH of protein solution after enzymatic hydrolysis, was lower than that of the reference casein (89.4%). The enzymatic digestibility of raw peanut was 63.2–83.1%, and it was 74.2–93.2% for heat-processed peanuts (boiling, 100°C, 60 min; roasting, 170°C, 3 min; and frying, 135°C, 6 min) depending on peanut variety and heat treatment conditions (Anurag & Geervani, 1987).

In biological studies, the true digestibility of peanut meal was 93.6–94.7% (Neucere *et al.*, 1972) and was 91–98% for peanut flour (Singh & Singh, 1991). It seems that the enzymatic digestibility method as described by Satterlee *et al.* (1982) underestimated the digestibility of the protein in the beverage. Also, Ruales & Nair (1994) reported that the enzymatic digestibility method underestimated the true digestibility of quinoa seeds by 10%. The protein digestibility corrected amino acid score (PDCAAS) of the beverage is 34%, and it is 114% for milk.

Mineral content (Table 6) of the beverages sterilized (137°C) for 4 or 20 s were similar. The beverage contained relatively high amounts of potassium, sodium and magnesium. Contents of minerals in the beverage may vary depending on mineral content in the raw material. Peanut kernels were reported to contain up to 26 minerals, of which potassium, phosphorus, magnesium and sulphur are usually present in relatively high concentrations (Woodroof, 1969). Some workers (Deosthale, 1981; Akrida-Demertzi *et al.*, 1985) observed considerable variations in the contents of minerals in peanuts, depending on the seed variety and geographical origin. Also, the type and amount of fertilizer used influenced the mineral content of the peanut (Gaines & Hammons, 1981).

The beverage contained significantly lower amount of calcium (5.5 mg/100 g beverage) than the level recommended (PAG, 1973) for milk-substitutes of vegetable origin ($\geq$ 100 mg/100 g drink). Also, content of calcium in the beverage was lower than that in milk (120.0 mg/100 g milk) and in a commercial soybean beverage (17.0 mg/100 g beverage).

Anaemia, a consequence of iron deficiency, has been estimated to occur in 46–51% of children in low-income countries (Simeon & Grantham-McGregor, 1990). The beverage contained appreciable amounts of iron (0.5 mg/100 g beverage), in connection with the level recommended (PAG, 1973) for milk-substitutes of vegetable origin ($\geq$ 0.4 mg/100 g beverage). Studies (Christian & Seshadri, 1989) on availability of iron from milk, soybean beverage and peanut beverage revealed that the percent available iron was highest in milk (21.2%) followed by peanut beverage (15.5%) and soybean beverage (12.3%). Moreover, addition of milk or peanut beverage enhanced the availability of iron from a standard cereal meal whereas soybean beverage did not.

Contents of vitamins in the beverages (Table 6) sterilized (137°C) for 4 or 20 s were similar. According to the guidelines of the Protein Advisory Group (PAG, 1973) for milk-substitutes of vegetable origin, the beverage contained appreciable amounts of thiamin, folic acid and niacin. However, the beverage had lower contents of vitamin A, riboflavin and vitamin C.

The nutrient density of the beverage sterilized (137°C) for 4 s, based on the recommended dietary allowance for adult males between 19 and 50 years old is

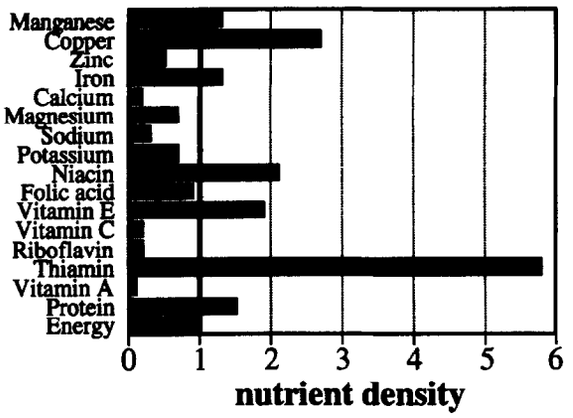

Fig. 2. Nutrient density of peanut beverage UHT-sterilized at 137°C for 4 s. Nutrient density is the ratio between the amount of nutrients present in the material that is enough to provide 2800 kcal, and the amount of nutrients recommended for male adults between 19 and 50 years old.

illustrated in Fig. 2. The nutrient density is an index of food quality; it relates its contents of energy and nutrients to specific needs of the human. A food with nutrients in excess of calories (i.e. nutrient density is greater than 1) is of good quality. However, a food with nutrient density less than 1 is of inferior quality, and a person would have to consume excessive calories from that food to obtain the recommended quantities of nutrients (Hansen, 1973). Accordingly, the peanut beverage can satisfy the requirements for thiamin, vitamin E, niacin, iron, copper and manganese recommended for adult males in the age group 19–50 years (Kreutler, 1980). On the other hand, it has lower nutrient density for vitamin A, riboflavin, vitamin C, calcium and zinc.

CONCLUSIONS

Sterilization at 137°C for 4 or 20 s gave commercially sterile beverages, of comparable microbiological quality. Therefore, the product is of potential advantage for the temperate low-income countries with peanut as a major crop and where refrigeration facilities are not easily available. However, not only the microbiological quality, but also changes in physicochemical and sensory properties during storage of the beverage need to be investigated in order to determine its shelf-life.

The beverage is a lactose-free, nutritious food item. If the beverage is used as a milk-substitute to nourish lactose-intolerant infants, it may be fortified with the necessary amino acids, vitamins and minerals to bring its nutritional quality up to the recommended levels.

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